Development of a multi-plant cross-function roadmapping tool: an industrial case in Food&Beverage sector

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Abstract. The sector of Food & Beverage (F&B) has experienced a remarkable increase in the diversification of products, leading to a consequential increase in variability, which, if not properly managed, would result in tampering profitability. Assuming that this trend cannot be reversed, manufacturers must foster their operations' efficiency, thus sustaining their competitiveness. Industry 4.0 (I4.0) paradigm is recognized worldwide as one of the preferred paths to address this issue. By following the digitalization path, companies may encounter different barriers and will require support to overcome them. Specifically, MNCs require to exploit existing synergies among different plants and build common infrastructures. This paper presents a methodology aimed at creating a unified roadmap (TRM) for multi-plant manufacturing companies. The methodology is then applied through an industrial case study to enable the desired digital transformation of a whole MNC's country branch, starting from the MNC's objectives and the digital maturity assessment of the single plants. The industrial case, the Italian branch of a Swiss MNC (3 plants), allowed to support C-Levels in identifying the priority areas at subsidiary level and in allocating resources accordingly. Regarding the theoretical implications, the research allowed to shift from a single-plant view, adopted by several TRM studies, to a cross-plant cross-function integrated approach.

Keywords: Food & Beverage, Manufacturing, Digital Transition Roadmapping, Industry 4.0, Assessment

1 Introduction

The digital transformation is spreading worldwide, influencing the entire society and, in the industrial field, the influences are reflected in the operations of several manufacturing sectors [1]. Among all, Industry 4.0 (I4.0) technologies are considered great drivers for improving manufacturing companies' efficiency and this is true especially for the food and beverage (F&B) sector [2]. The F&B sector is being asked to improve its sustainable oriented performances to ensure a balanced and proper resource management willing to exploit the value of the waste generated along the entire value chain [3]. To accomplish these goals in an efficient manner, the F&B sector is required to rely on the technological advancements by selecting the right technologies according to the specific needs [4]. The choice of the right technology is fundamental for both small and medium companies, to prudently use financial resources for technological investments but also for Multinational Companies (MNC)s [5] which are required to balance the investments in their dispersed plants, sometimes acquired from other companies along the years, by tailoring the technological introduction on the needs of each plant. In this context, it is fundamental to design a unified roadmap tailored on the strategic goals of the company as a whole while keeping into account the specific needs and digital maturity levels of its dispersed plants. Nevertheless, at the best of the authors knowledge, few contributions proposed multi-plant perspective. In this regard, the present contribution aims at developing a roadmapping tool to support digital transition of multi-plant manufacturing companies. The proposed methodology has then been validated through an industrial case study, involving a multi-plant company operating in the F&B sector. To address the research objective, the following research question has been formulated "How to support multi-plant manufacturing companies in the transition towards industry 4.0?". The developed roadmapping tool has been designed through the integration of a literature review on maturity models and roadmapping tools with an action research approach. Both the development methodology for the roadmapping tool and the results obtained out of the application of the tool are showed in this contribution highlighting the key practical and theoretical implications. The remainder of the paper is structured as follows. Section 2 describes the theoretical background used as a basement to develop the tool. Section 3 elucidates material and methods applied to the analyzed case study. Section 4 shows application of the model. Section 5 discusses the results obtained, while Section 6 concludes the contribution paving the way to future research opportunities.

2 Theoretical Background

Digital transformation and Industry 4.0 are relevant trends impacting manufacturers' operations. Looking at the barriers faced by manufacturers in digitalization effort, lack of competences and direction stand amongst the major ones [6] thus highlighting that a concrete support is essential to enable the change [7]. In this direction, Technology Roadmaps (TRMs) prove to be a valuable and sounded solution [8]. Although the concept seems quite established in literature, as it was first introduced in the 1960s [9], it has been evolving over time in parallel with the industry's technological advancement [10]. As a matter of fact, a clear and shared definition is difficult to detect even though, considering the scope of the research proposed, the authors adopted the one coined by [11] which define TRM as "*a process that mobilizes structured systems thinking, visual methods and participative approaches to address organizational challenges and opportunities, supporting communication and alignment for strategic planning and innovation management within and between organizations at firm and sector levels*". From this definition it can be noticed that TRM lays its value in the process of creation rather than the tool itself . For this reason the methodology should present certain characteristics such as: being shared by the company involved [12], being multi-functional [13], being aligned with corporate strategy [14] and being easy to learn [15]. In particular, [16] highlighted that the success of a transformation roadmap in manufacturing context might be maximized whenever a multi-dimensional approach is adopted including, among the others, operations processes and people and skills. The roadmapping process is constituted by a series of consecutive steps that lead to the development of the TRM. Again, literature has proposed plenty of methodologies which differ in relation to the steps to reach the outcome and, to some extent, also in terms of considered dimensions. In this direction, a subset of the most rated methodologies that differs by steps and dimensions adopted is provided in **Table *1***.

Table 1 Main TRM methodologies' dimensions considered and phases

Reference	Dimensions	Phases
[17]	Technology, product, and market	5
[18]	Not provided	8
[19]	Not provided	4
[20]	Partners, resources, supplementary technologies, core technologies, product, and market	3
[14]	Not provided	6
[15]	Technology, product and market	4
[21]	Customer, benefit, value-creation, partners, and finance	5
[22]	Markets, product, technology, regulations/standards, organization, and value goals	-
[23]	Product conformance, product performance, and objectives & target	5

Although roadmapping is the application of multiple phases, literature has focused its attention mostly on only one preliminary phase: the maturity assessment analysis. The theory behind Maturity Models (MMs), sometimes referred as Readiness Assessments, is hence rich and covers multiple fields of research, including digital transformation in manufacturing. MMs are defined as "*evaluation tools to analyze and determine the level of preparedness of the conditions, attitudes, and resources, at all levels of a system, needed for achieving its goal(s)*"[24].

Among the MMs developed so far, [25] proposed a methodology, the DREAMY4.0, designed specifically to assess the most critical manufacturing process, namely R&D, Production, Quality management, Maintenance, Logistics and Supply Chain, to be kept under control to facilitate the digital transformation of the company. In particular, the methodology, based on a 5-level ranking, aims at providing a score of the above-mentioned functions and evaluate them under 4 different dimensions. The four dimensions assessed are: technology, in relation to the advancement of software and hardware used, Execution, intended as the correctness in carrying out the core activities, Monitoring and Control, to assess the capability to supervise efficiently and effectively the processes and Organization, to assess the alignment between the organizational structure and the processes governed.

3 Methodology

The authors took inspiration from existing literature to address the research objective of developing a roadmapping tool to support digital transition of multi-plant manufacturing companies. From the analyzed literature the authors have extrapolated 6 main roadmapping phases which are:

1. The understanding of the needs: which aims at collecting the necessary information to understand to strategic direction that the company is willing to undertake
2. The maturity assessment, or AS-IS analysis: which aims at understanding the current level of digital and sustainability maturity level within the subject of analysis and define the goals
3. The identification of problems and criticalities: which aims at critically analyzing processes to detect weaknesses that impede the company to achieve the desired goals and threatens performances
4. The definition of actions for improvement: which aims at identifying feasible solutions to overcome the weaknesses and support firms in achieving the desired scenario
5. The roadmapping, or planning: which aims at defining the necessary transformation journey to support organizations to achieve the stated goals
6. The control: which aims at monitoring the outcomes of the projects proposed and validate the roadmap or, on the contrary, adjust it

The roadmapping tool applied to the case study follows these phases. As suggested by [26], the roadmapping process was conducted through workshops with managers and operators of the main areas analyzed (i.e., Production Planning, Production, Energy Monitoring and Maintenance, Logistics).
Fig. 1 shows the steps representing the roadmap generation.

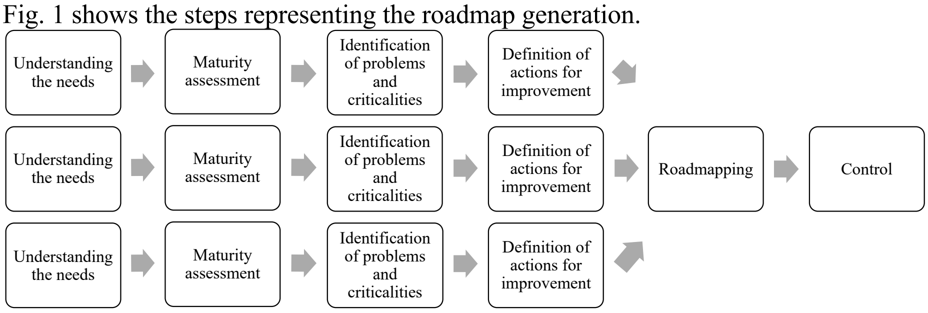

Fig. 1 Steps of the research conducted

Stage 1 was conducted through a an extensive interview with the top management teams, when the main strategic objectives of the firms were delineated. The AS-IS analysis (stage 2) was conducted by exploiting the DREAMY4.0 assessment model [25]. The identification of criticalities and their prioritization (stage 3) employed a simplified PCIM (Priority Criticality Index Mapping) approach proposed by [7] which encompassed a score assignment to the problems identified through face-to-face interviews with managers and process owners. In particular, the authors adopted a 2-dimensional compounded Likert scale based on 3 level, from 1 (low) to 3 (high). The 2 dimensions identified for the prioritization of criticalities adopted were i) the frequency of occurrence of the problem arose and ii) the impact registered on operations processes if or when the problem would manifest (see **Fig.** ***2***).

F/I	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9

Fig. 2 Ranking system for criticality prioritization (F: frequency; I: impact)

Furthermore, to better guide the solution development process, each criticality comprised a classification procedure aimed at identifying 3 main types, namely: i) Technology-based criticalities ("Tec" in Tab. 3), ii) Process-related criticalities ("Pro" in Tab. 3) and iii) Criticalities due to organizational incoherencies with processes or technologies adopted ("Org" in Tab. 3). Regarding stage 4, the definition of actions for improvements were validated by manufacturers' experts and managers. In stage 5 the actions proposed are valuated according to objective criteria decided with the company, then, they have been plotted in a roadmap and distributed over the given time horizon.

4 Roadmapping Tool Application

The methodology, illustrated in the previous section, has been applied to a multi-plant company operating in the F&B sector. The company owns three plants located in Northern Italy, which were used as industrial cases study.

According to stage 1 of the proposed methodology, a preliminary interview was conducted with the top management to clarify the strategic objectives of the group. The identified objectives are the following: i) increase efficiency, ii) reduce costs, iii) increase data reliability to improve short- and long-term decision making and iv) achieve the homogeneity of processes and architecture while preserving the product specialization of each plant. During this meeting, the IT manager of the group's Italian branches was also involved to clarify the peculiarities of the IT infrastructure. The three plants are characterized by different digitalization levels and have different and not integrated IT architectures. The digital infrastructure of the plants appears currently inadequate to address the global needs of the company: certain required systems are missing, and others do not meet the requirements of companies' operations. The inadequacy of the IT architecture could prevent the company to achieve the strategic goals set.

The authors then dedicated a full 2-days session for each plant (see Table 2) to conduct the interviews aimed at addressing stage 2 and stage 3 of the roadmapping methodology to assess the current AS-IS.

Table 2 Structure of the interview sessions

Step	Activity	Participants	Duration
1	Corporate strategy: objectives / main challenges / ongoing and future projects	Top management and IT manager	3 h

1	Plant operational strategies: objectives / main challenges / current and future projects	Plant managers	2,5 h
2	Factory tour + Interviews to key process managers	Key process managers	3 days (1 each plant)
3	Workshop to identify and map main current criticalities	Key process managers	3 days (1 each plant)
4	Identification and Prioritization of improvement projects	Company referees	1 day
5	Digital transformation plan discussion	Top management	4h

Through the separated interviews, it was possible to highlight the presence of common criticalities that are reported in Tab. 3. Indeed, the criticalities sometimes resulted to be specifically linked to the inefficiencies of a single plant, but, in other cases, these were shared among the plants due to some transversal similarities. Based on the PCIM, using the prioritization scale reported in Fig. 2, the common criticalities were considered the most impactful and thus were used to set the basis for the unified roadmap. The list of the most impacting criticalities and the area of responsibility are reported in Tab.3.

Table 3 Criticalities and their prioritization

Area	Criticality	PCIM Prioritization			Type
		Plant 1	Plant 2	Plant 3	
Planning	Production orders entered by hand on management system	Not present	9	6	Tec
Planning	Ineffective scheduling carried out on Excel	Not present	9	9	Tec
Planning	Information on the availability of non-system personnel	Not present	6	6	Tec
Planning	Paper-based shared production order	6	Not present	3	Org/Tec
Production	Manual progress of production monitoring	6	Not present	3	Tec
Logistics	No storage policies are defined	9	6	9	Tec/Pro
Maintenance	Shortage of KPIs for process monitoring	9	6	6	Org/Tec
Maintenance	Unstructured interventions History	9	Not present	6	Proc/Tec
Maintenance	No on-call assignment policy	6	3	Not present	Proc
Maintenance	Limited data usage	6	Not present	6	Tec

As shown in Tab. 3 and reported in the methodology section, the criticalities can be reconducted to three main types: process, organizational or technological. Numerous criticalities are connected to processes implemented over time to overcome the inadequacies of the IT systems. Other criticalities are related to the activities that, although might be automated, are currently carried out manually because of lack of proper technologies and/or lack of competencies. This issue increases inefficiency and forces employees to perform non-value-added activities. The lack of adequate digital supports creates problems such as that relevant information is communicated verbally or via paper-based documents, fostering possible mistakes due to information loss. Moreover, all the analyzed plants appeared to not be able to punctually collect and analyze all relevant data related to certain company's activities, such as production, maintenance, and logistics. These inefficiencies are identifiable from the most common criticalities shared between plants (collected in Tab. 3).

The production planning areas operate on IT systems inadequate to plants' needs. To overcome IT limits, the production orders are inputted manually on the ERP and are then shared on paper-based documents. Moreover, in those plants where the planning software is missing (i.e., plant 2 and plant 3), the production plan is redacted on an Excel file.

Due to IT infrastructure's limitations, the production area is not able to monitor in real time the production's progress, which has to be updated manually.

Similar criticalities can be identified in the maintenance area: few KPIs are collected and monitored, and the record of maintenance activities is not structured, preventing the managers to conduct punctual analysis.

In the logistic area, storage criteria are not defined and those which are defined are not shared coherently among all people operating in that area.

Despite the differences between single plants, it was possible to observe that distinct criticalities could be addressed by shared solutions. Indeed, specific solutions could be reconnected to transversal projects, shared by all plants. Improvement projects have been identified and prioritized together with the continuous improvement team and, thanks to this effort, the strategic unified digital roadmap has been developed and shared with the top management to implement the prioritized projects in a conscious and structured manner.

In Fig. 3 is shown the unified roadmap covering the criticalities emerged during the assessment. The projects focus both on processes' and IT architecture's improvements. The roadmap is structured along a timeline, and the first projects aim at solving processes' inefficiencies to facilitate the adoption and implementation of the adequate IT systems. Taking into consideration the relevance of human resources in the digital transition, certain projects focus on fostering, by mapping and improving the skills' baseline of people, the appropriate digital culture required to operate in the new system. In accordance with the review of the internal processes, it is suggested to identify the requirements of the new IT systems needed to answer the needs of processes and plants. The projects related to IT infrastructure aim at reinforcing the digital backbone of the firm, proposing adequate tools shared between plants, and at fostering the adoption of industry 4.0 standards and technologies at group level, creating an infrastructure for data collection, analysis and usage.

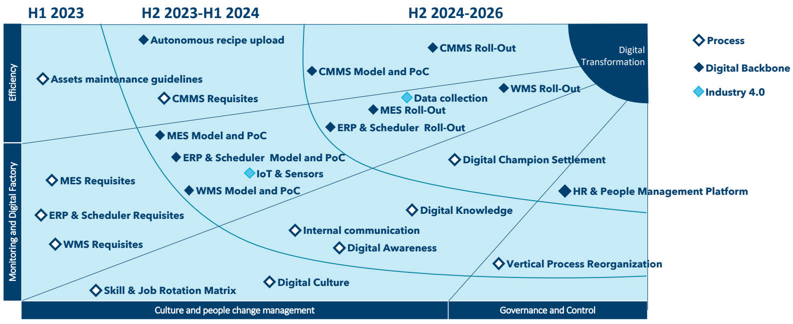

Fig. 3 Proposed Roadmaping output

5 Discussions

This contribution highlights the possibility to propose a unified roadmap based on the the assessment of multiple plants across several functions. The methodology enables to overcome relevant criticalities, either plant-specific or transversal between all the plants. Therefore, this research has twofold implications: both theoretical and practical. From a theoretical perspective, the presented roadmapping methodology shows the possibility to move from the single-plant view, on which most of the TRM studies are focused, to achieve an approach aiming at integrating both functions and plants within a single roadmap. The research, hence, highlights how a cross-plant and cross-function approach can answer the requirements of MNC companies, which desire to achieve a higher digitalization level across multiple plants in the same timeframe and in a structured manner. From a practical perspective, the methodology supports C-levels in the appropriate allocation of resources dedicated to the processes' digitalization. By analyzing at the same time different plants, with different characteristics in terms of culture, processes, and IT infrastructure; the proposed methodology allows the identification of shared criticalities, impacting of the overall inefficiencies of the group, and the development of a common roadmap. The proposal of a unified roadmap guides the company in the definition and selection of transversal projects, optimizing efforts and invested resources (both economic and human), reaching in multiple plants similar digitalization levels. Moreover, it facilitates the implementation of homogeneous processes and IT architecture, and the transfer of best practices among the different plants. Nonetheless, the methodology applied has limitations: it has been applied to a single company case study and future research should validate the procedure in other manufacturing industries. Moreover, step 6, "control", has not being implemented. The boundaries of the case study were temporarily limited, and the outcomes' monitoring activity was not included. Future research should apply to a broader timeframe.

6 Conclusions

The objective of this research was to propose a roadmapping methodology to guide multi-plant companies in the creation of a unified roadmap, shared between multiple plants with distinct characteristics. Indeed, existing literature mostly focuses on TRM with a single plant-view, while the authors observed the need of overcoming this silos approach to support MNCs in creating a unique roadmap shared between multiple plants. The authors proposed a cross-plant cross-function methodology and applied it to an industrial case in the F&B sector. The contribution illustrates that the methodology can answer multi-plant companies' requirements: assessing distinct criticalities, identifying improvement projects, and proposing an unified roadmap, shared between multiple plants and functions. The research presents limitations such as the application to a single case study and the lack of a control phase. Future research could investigate whether the proposed methodology is effective on companies in different sectors, presenting a higher number of plants or with higher diversity between the plants themselves.

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